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STRAIN MEASUREMENTS ON MIRAGE WING SPAR WITH BFRP PATCH FITTED TO DRAIN-HOLE REGION

B.C. HOSKIN and A.A. BAKER

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SUMMARY

Strains have been measured in a Mirage wing with an eight-layer boron fibre reinforced plastic (BFRP) patch fitted in the region of a fuel drain hole, during a series of ground calibration loadings. The point of these measurements was to determine whether the patch caused any significant, and potentially deleterious, changes in the strains in the main spar. It was concluded that no deleterious changes occurred.

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16. ABSTRACT:

Strains have been measured in a Mirage wing with an eight-layer boron fibre reinforced plastic (BFRP) patch fitted in the region of a fuel drain hole, during a series of ground calibration loadings. The point of these measurements was to determine whether the patch caused any significant, and potentially deleterious, changes in the strains in the main spar. It was concluded that no deleterious changes occurred.

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A

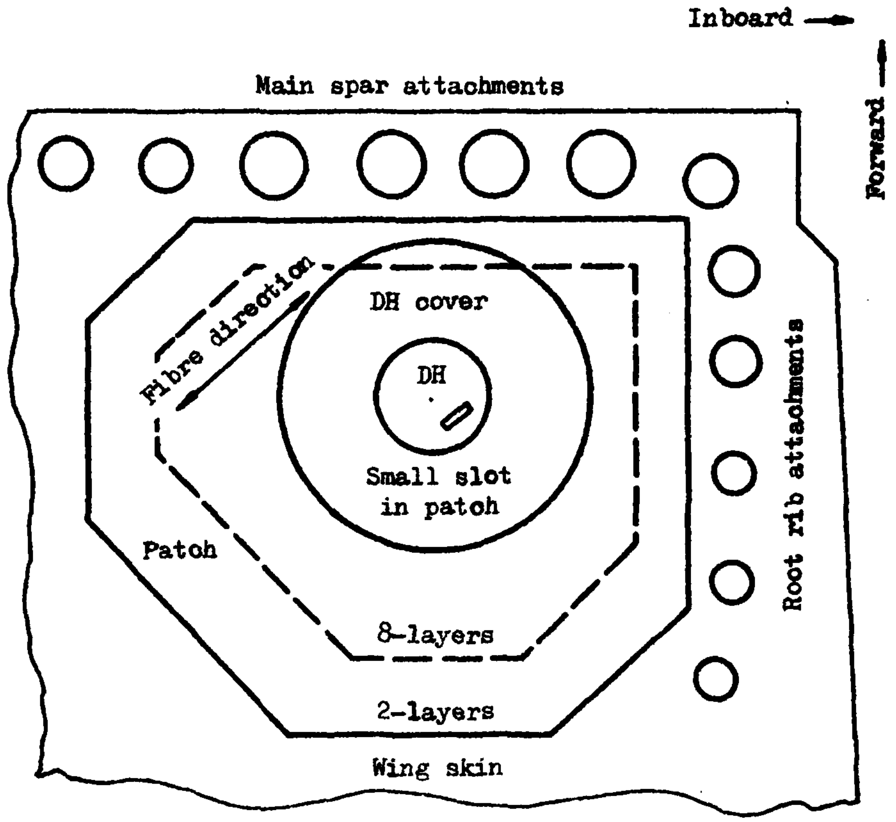
1. INTRODUCTION

Fatigue cracks have occurred in the region of a fuel drain hole in the lower wing skin of several RAAF Mirage aircraft. Following a request from the RAAF, ARL undertook to develop a boron fibre reinforced plastic (BFRP) patch to serve as a field repair for this region. One requirement of this patch repair was that it should not cause any redistribution of strains in the main spar (which is adjacent to the patched region) such as could have a detrimental effect on the fatigue life of the spar. As it happened, at the time this problem arose a Mirage, one of whose wings had been extensively strain-gauged, especially along the main spar, was undergoing a series of calibration loadings on the ground in connection with a general investigation of Mirage fatigue. It was decided to apply a patch to this strain-gauged wing so as to investigate experimentally any changes in spar strains associated with patch application.

2. BFRP PATCH FOR TEST WING

The BFRP patch was fitted to the left wing of the Mirage which was being utilised in the ground-loading strain survey conducted at Avalon, Victoria. The location of the patch (on the external surface of the lower wing skin) is as shown in Fig. 1. The patch is stepped in thickness, one layer of BFRP at a time, from a minimum of two layers to a maximum of eight layers; each layer of BFRP is approximately 0.13 mm thick. Whilst the diameter of the drain hole in the skin is 32 mm, there is no such matching hole in the patch; instead the patch has a small slot 12 mm X 3 mm in it. (This modification was accepted by the RAAF.) The patch does have the eight holes (each of approximately 4 mm diameter and not shown in Fig. 1) which permit the bolting on of the standard metal drain hole cover and drainage nozzle; this last is sometimes referred to as the "decant boss". The patch was bonded to the wing using a cold setting adhesive, namely, CIBA AY105, HY956; contact pressure was applied to the patch during the bonding. A view of the patch as fitted to the wing is shown in Fig. 2.

It should be mentioned that the tests to be described here were carried out fairly early in the overall patch development programme and there is some difference between the above patch and the one that is actually being used for repair of the fleet. In particular, for fleet repair a seven layer patch is used; this has the same general configuration as the patch shown in Fig. 1 except that the thickness is stepped from one layer to seven layers. However, insofar as the effect of the patch on spar strains goes, the eight-layer patch represents a more severe condition in the sense that if it be demonstrated that the eight-layer patch has no significant effect on spar strains, then it may be concluded that neither does the seven-layer patch. Also, it should



DH = drain hole

FIG.1 BFRP PATCH FOR DRAIN HOLE REGION OF STRAIN SURVEY WING
(approx. half scale)

FIG.2 PHOTOGRAPH OF PATCH FITTED TO THE MIRAGE WING;
The strain gauges bonded to the patch and the aircraft skin can be seen.

be pointed out that, for fleet repair, a hot-setting adhesive with a cure time of two hours at 120°C is used to bond the patch to the wing skin. The hot-setting adhesive has much better fatigue and environmental performance than the cold-setting adhesive used in the present tests, although the latter is considered equally effective for static load transfer. It was necessary to use the cold-setting adhesive here so as to avoid the risk of damaging strain gauges already attached to the wing.

3. TEST PROCEDURE

The main spar of the test wing had fifteen electric resistance strain gauges fitted to its lower spar flange between stations 850 and 1260. (Spar stations are actually the distances in mm outboard of the fuselage centreline. The BFRP patch extends in the spanwise direction from station 810 to 980.) Gauges were variously fitted on the front (two possible positions), centre (one possible position) and rear (two possible positions) of the spar flange as shown in Fig. 3a. The spanwise positioning of the gauges is shown in Fig. 3b. Complete details on gauge locations are given in ref. 1. All gauges measured tensile strains in the spanwise direction.

Load was applied to the wing by a single jack acting upwards at a single wing hard-point. In one series of tests the point of load application was at what is known as the "main store position"; this is at station 2250 on the main spar. In another it was at what is known as the "Sidewinder position"; this point is 1405 mm aft of the main spar at station 3080. The maximum load applied at the main store position was of the order of 22.25 kN (2273 kgf) and at the Sidewinder position it was of the order of 16.465 kN (1682 kgf). For all tests the aircraft was supported at fuselage stations 1545 and 7375, and load was applied symmetrically to each wing.

In the general investigation of Mirage fatigue there is considerable interest in whether the absence of the wing-fuselage fairing has any effect on the strains in the wing. Although this point is not relevant to the present investigation, nevertheless it was convenient to do runs both with "fairings off" and with "fairings on".

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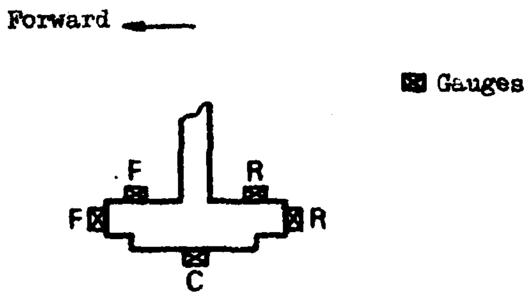
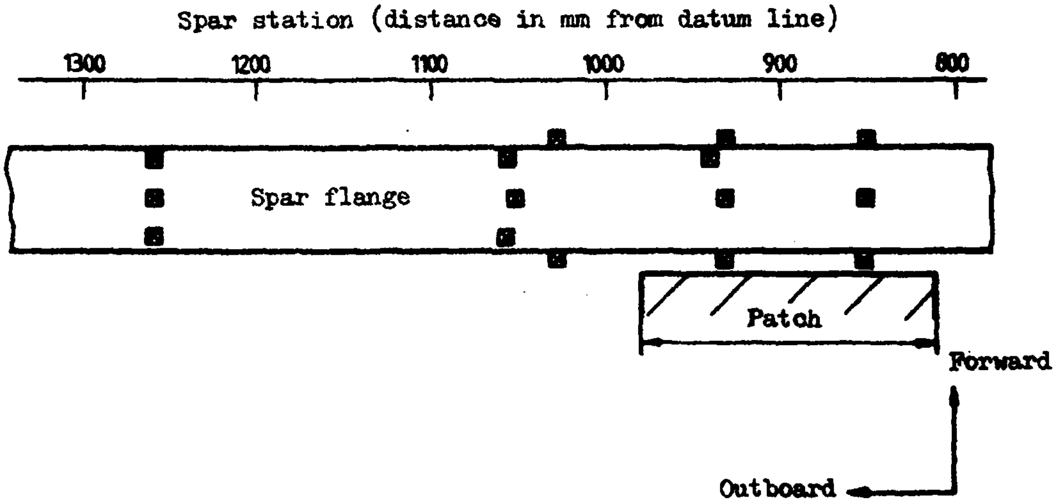
1. Mirage Strain Survey Gauge Positions, ARL Drg. No. 54020, Revision No. 6, 31 October 1978.



a) Various gauge locations on front (F), centre (C) and rear (R) of lower spar flange.



b) Spanwise location of gauges.

FIG.3 LOCATION OF STRAIN GAUGES ON LOWER SPAR FLANGE OF TEST WING.

For each of the four cases, arising from two points of load application and the two fairing configurations, spar strains were measured before and after fitment of the BFRP patch. Generally, two loading runs were made for each case but experience has shown that significant hysteresis effects can occur in loading the wing; these effects have been assessed as being smaller in the second run and, for that reason, strains as measured in the second of two runs have been used for the present comparison.

4. TEST RESULTS AND DISCUSSION

The results are shown in Tables 1 and 2, where all strains have been cited as microstrains. In all cases the strain as actually measured at the maximum applied load has been standardised to the value corresponding to an applied load of 9.80 kN (1000 kgf); this standardisation was made on the assumption of a linear variation of strain with load. Corresponding values of strain before and after patch application are shown alongside one another, and the percentage increase in strain after patching has also been calculated. This last is defined as ((patched value-unpatched value)/unpatched value) X 100. The percentage increase in measured strain is also shown in Figs. 4 and 5. (For convenience of presentation, the results for the three gauges at station 1256 - which is well beyond the end of patch - have been omitted from Figs. 4 and 5).

Considering first the case of "fairings off", the maximum increase in measured strain anywhere is 2.5% at gauge 324T for loading at the Sidewinder position. With the exception of this result, and the measured decreases of 8.8% and 8.6% at gauge 323.2T, and 4.1% and 3.2% at gauge 1.7T, all other measured changes lie within the range +2.5% to -2.5%. In fact the only other increase in excess of 2% is for gauge 1.6T (Table 1).

For the case of "fairings on", the maximum increase in measured strain is 4.8% at gauge 323.4T for loading at the main store position. There are also several other apparent increases in excess of 2.5%, including two such results for the gauges at station 1256 (Table 1). However, it should be stated that experience in strain measurements on the Mirage wing has shown that the degree of tightening of the fairing attachment bolts affects the spar strains in the "fairings on" cases. This was not fully appreciated at the time some of these tests were done and, bearing in mind the relatively small differences that are being measured, there are doubts as to whether the apparent increase in spar strain at some locations can be properly attributed to the presence of the patch. For example, on intuitive grounds, it

TABLE 1: SPAR MICROSTRAIN PER 9.80 kN (1000 kgf) AT MAIN STORE POSITION

Strain Gauge			Measured Microstrain					
No.	Location		Fairings Off			Fairings On		
	Station	F,C or R*	Unpatched 6103R**	Patched 6303**	Increase %	Unpatched 5233 BE**	Patched 6403**	Increase %
324T	852	R	163.5	162.6	-0.6	-	151.1	-
324.1T	852	C	222.0	220.2	-0.8	208.8	214.1	2.5
324.2T	852	F	179.7	176.4	-1.8	180.0	181.3	0.7
323.1T	932	F	171.4	172.7	0.8	175.3	174.0	-0.7
323.2T	932	R	114.4	104.3	-8.8	100.1	98.1	-2.0
323.3T	932	C	181.1	178.9	-1.2	169.8	173.4	2.1
323.4T	936	F	126.7	127.6	0.7	121.4	127.2	4.8
223T	1048	C	171.4	170.7	-0.4	161.3	165.7	2.7
1.4T	1054	F	139.3	140.1	0.6	134.6	140.1	4.1
1.6T	1029	F	153.1	156.4	2.2	151.1	156.9	3.8
1.7T	1029	R	125.2	120.1	-4.1	114.2	114.6	0.4
1.8T	1054	R	132.2	129.8	-1.8	121.9	125.0	2.5
2T	1256	F	128.5	128.5	0.0	121.9	126.3	3.6
2.1T	1256	R	120.1	118.4	-1.4	-	117.0	-
2.2T	1256	C	154.0	154.0	0.0	145.2	149.8	3.2

* Front (F), centre (C) or rear (R) position on spar flange.

** Identification number for test.

TABLE 2: SPAR MICROSTRAIN PER 9.80 kN (1000 kgf)
AT SIDEWINDER POSITION

Strain Gauge			Measured Microstrain					
No.	Location		Fairings Off			Fairings On		
	Station	F,C or R*	Unpatched 6106R**	Patched 6306**	Increase %	Unpatched 5236BE**	Patched 6406**	Increase %
324T	852	R	348.9	357.7	2.5	-	318.8	-
324.1T	852	C	356.6	355.3	-0.4	327.6	340.8	4.0
324.2T	852	F	237.2	232.1	-2.2	-	226.4	-
323.1T	932	F	235.4	236.9	0.6	239.4	234.5	-2.0
323.2T	932	R	183.3	167.6	-8.6	175.3	163.7	-6.6
323.3T	932	C	288.6	289.1	0.2	267.1	273.5	2.4
323.4T	936	F	192.3	190.7	-0.8	181.3	185.7	2.4
223T	1048	C	275.0	271.3	-1.3	254.5	252.6	-0.7
1.4T	1054	F	213.0	213.8	0.4	203.7	203.7	0.0
1.6T	1029	F	221.1	224.0	1.3	219.3	217.1	-1.0
1.7T	1029	R	223.5	216.3	-3.2	194.7	191.0	-1.9
1.8T	1054	R	217.1	212.5	-2.1	195.8	196.7	0.5
2T	1256	F	196.9	197.8	0.5	184.4	187.0	1.4
2.1T	1256	R	194.5	192.5	-1.0	179.5	181.7	1.2
2.2T	1256	C	242.4	239.8	-1.1	226.2	228.8	1.1

* Front (F), centre (C) or rear (R) position on spar flange.

** Identification number for test.

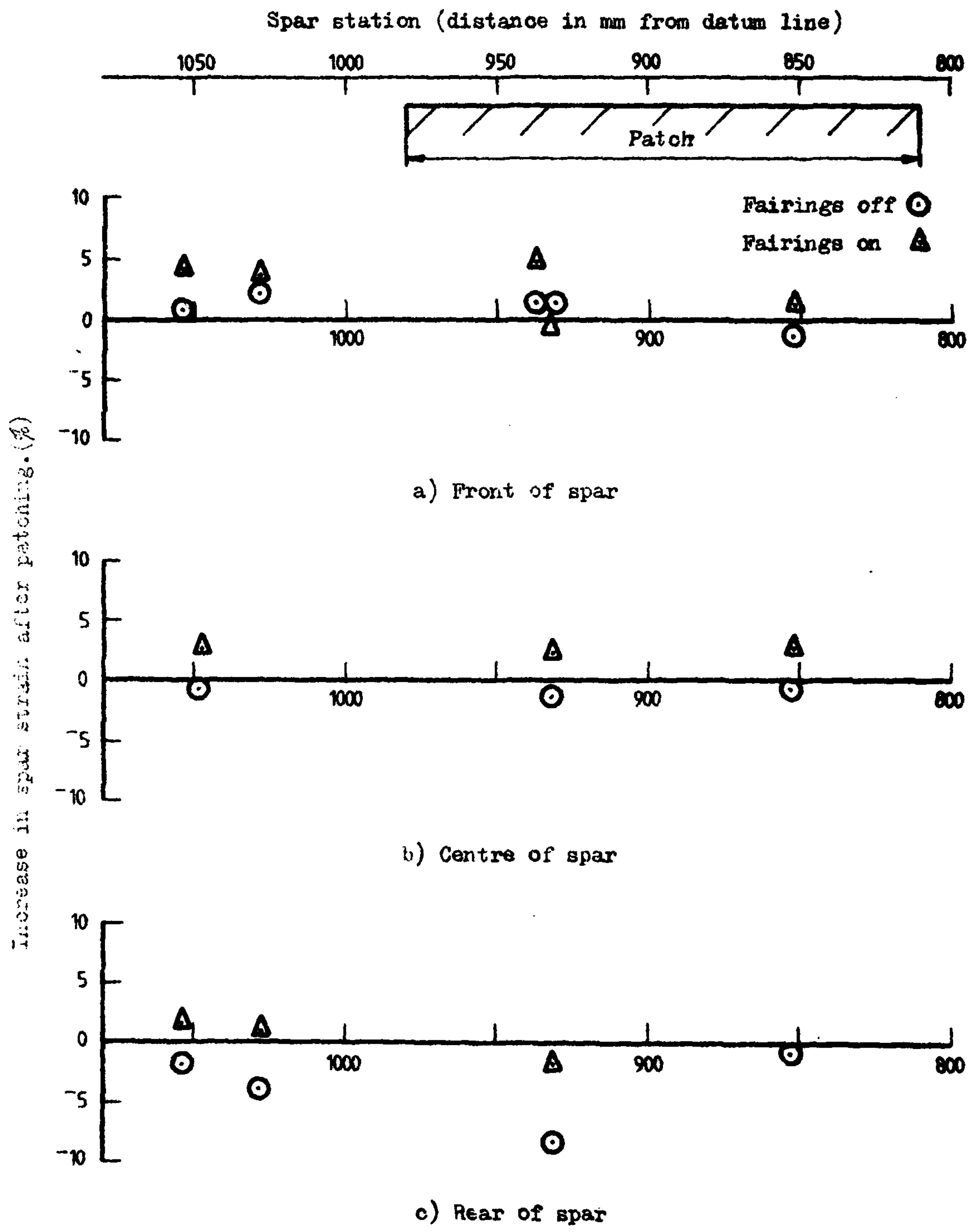


FIG.4 CHANGE IN SPAR STRAINS AFTER PATCHING; LOAD AT MAIN STORE POSITION.

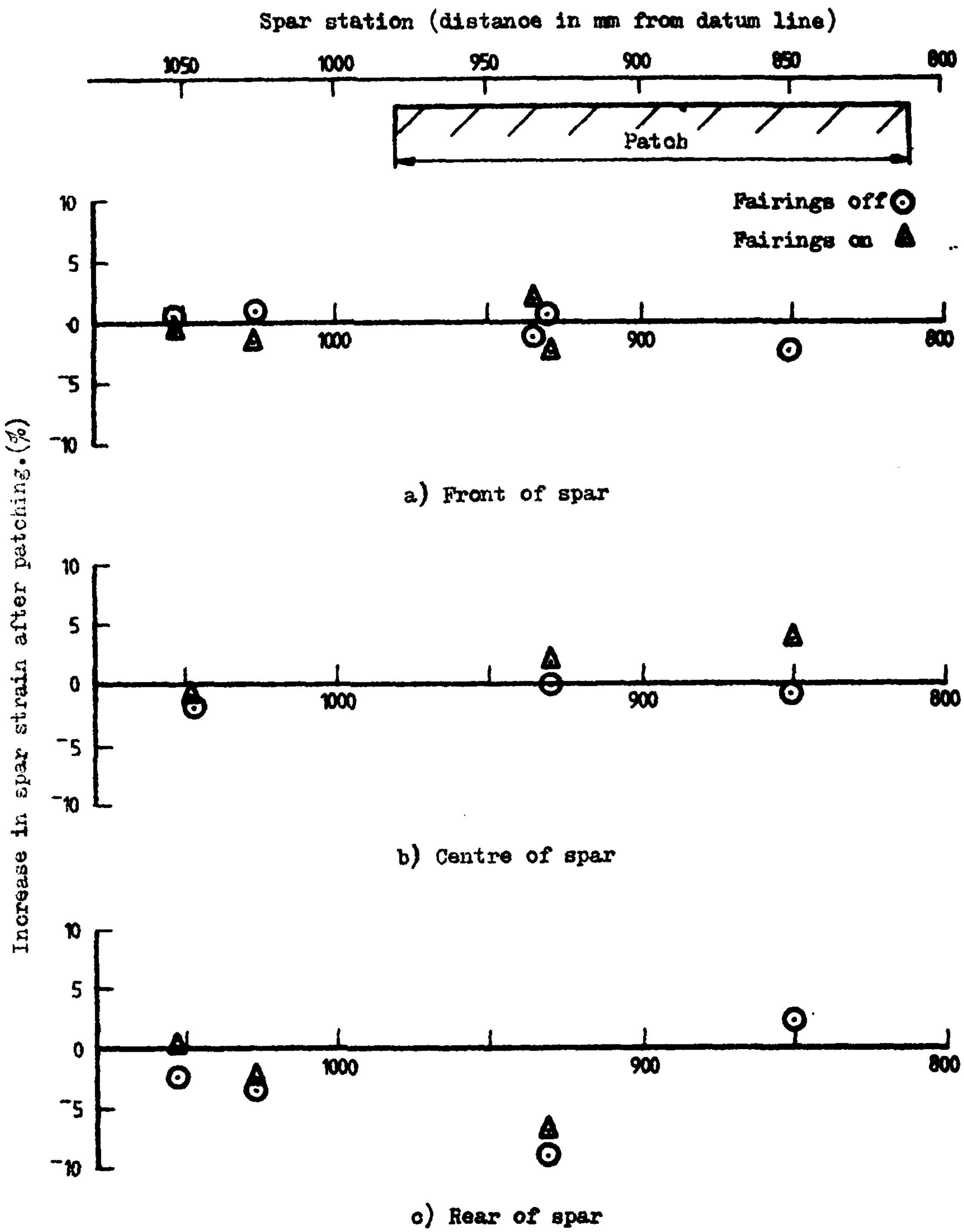


FIG.5 CHANGE IN SPAR STRAINS AFTER PATCHING; LOAD AT SIDEWINDER POSITION.

would seem unlikely that the patch should have a significant effect on the strains at station 1256 yet, according to Table 1, there is a 3.6% increase in gauge 2T. (Note that the maximum measured change at station 1256 for the "fairings off" case is -1.4%.) For the above reasons, the measurements made in the "fairings off" cases are considered to be more reliable as indicators of any effect due to patching. However, even taking the results for the "fairings on" cases at their face value, the measured increases are still considered small.

The apparent large decrease in the strain at gauge 323.2T in three out of the four cases is somewhat surprising, although of no cause for concern because it is a decrease.

In discussions with the RAAF (ref. 2), it was agreed that the criterion for acceptance of the patch as far as any possible effects on spar strains go, was that the increase in strain after patching should not exceed 5%. In the case of results obtained with "fairings off", and these results are considered the most reliable, the maximum increase in strain after patching was found to be 2.5%. For what are considered the less reliable results, with "fairings on", the maximum increase was 4.8%. Hence, in both cases, the 5% criterion is satisfied.

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2. Minutes of the 2nd LTCM between ARL and RAAF on BFRP Repair to Mirage Wing Cracks, 1 December 1978, para. 4.

5. CONCLUSIONS

As a result of measurements made in ground-loading tests, it is concluded that an 8-layer BFRP patch fitted to the drain-hole region of the Mirage wing causes no potentially deleterious changes in the strains in the main spar. Since the 7-layer patch being used for fleet repair must be expected to have even less effect than the 8-layer one in this respect, it can be concluded that it, too, will cause no potentially deleterious changes in spar strains.

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